DOCUMENT RESUME

ED 127 140 SE 020 872

AUTHOR Farrell, Margaret A.; And Others
TITLE Field Testing a Systems Analysis Model for Mathematics/Science Teacher Education.
PUB DATE [76]
NOTE 25p.; Not available in hard copy due to light and broken type throughout original document

EDRS PRICE MF-$0.83 Plus Postage. HC Not Available from EDRS.
DESCRIPTORS Instruction; *Mathematics Education; Objectives; *Performance Based Teacher Education; *Research; Science Education; Student Teachers; *Systems Analysis; Teacher Education; Teaching Methods
IDENTIFIERS Research Reports

ABSTRACT

A systems analysis model was developed as a conceptual framework for a program for teacher education in the fields of mathematics and science. The model related teaching competencies which had been identified previously by the researchers. The purposes of the research reported in this paper were to determine interrelationships among the competencies comprising the model, and to test the theoretical links between the model and the instrument designed for testing. Data were collected on student teachers (N=122) over a period of five semesters. The difficulty levels of items were ascertained and compared; items for which less than half the subjects met the criterion were identified and examined separately. Correlation coefficients were computed for pairs of competencies and submitted to factor analysis. The first seven factors identified were compared with the seven major model components: (1) nature of content to be learned, (2) intellectual development of students, (3) objectives specified, (4) how humans learn various categories of content, (5) instructional strategy design, and (6) feedback resulting from implementation of plans. (SD)

FIELD TESTING A SYSTEMS ANALYSIS MODEL FOR MATHEMATICS/SCIENCE TEACHER EDUCATION

by

Margaret A. Farrell, Walter A. Farmer and Richard Clark
State University of New York at Albany

Currently there is much interest in competency based teacher education but empirical studies in this area, particularly in secondary school mathematics/science teacher education, are lacking. However, there have been some team efforts in teacher education--e.g., the work of Cooney et. al. based on the theories of Henderson. There have also been implications for instruction in the works of Gagne, Ausubel, Piaget, and Bruner. Various national and regional groups (e.g., NCTM, AASTEC) have developed guidelines for identifying teacher competencies but, as yet, instruments tied closely to theoretical models and submitted to the test of data analysis do not appear in the literature. Since a growing number of states are mandating CBTE, it is important to conduct relevant research which ties together an identified theoretical basis for the approach and resulting data. The results of such studies should provide a basis for the development of future teacher education programs which will be both practical and generalizable.

The study reported here is based on the Albany Mathematics Science Teaching (AMST) program. The program, the systems analysis model on which it is based, and the evaluative instrument of teaching competencies were developed by researchers Farmer and Farrell in an effort designed to meet the need described above. The statistical design and analysis of the data were the major responsibility of researcher Clark.

Purposes:

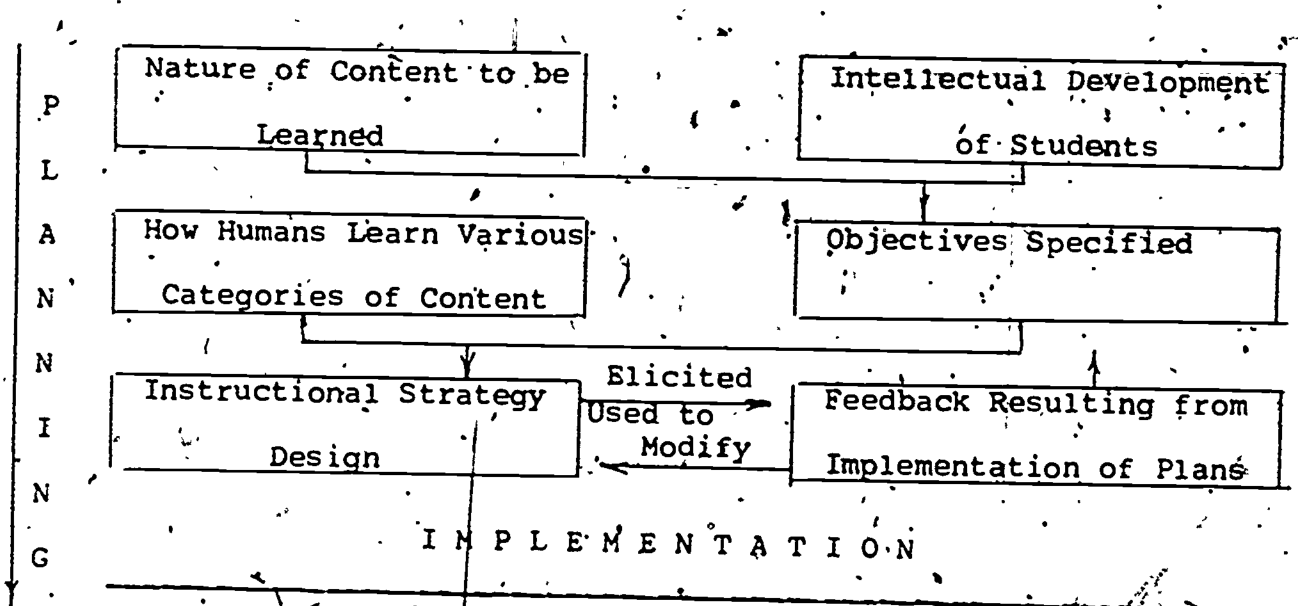
The two primary purposes of the total research effort relevant to this paper are:

1) to ascertain the inter-relationships among the separate competencies comprising the total instrument, and

2) to test empirically the theoretical lines of correspondence between the model and the competencies on the instrument.

Conceptual Framework:

The systems analysis model depicted below is based on prior experiences in supervising 500+ student teacher, the growing body of research evidence by cognitive psychologists such as Ausubel and Gagne and the developmental psychology of Piaget. This simplified model forms the conceptual framework for the Albany Mathematics Science Teaching Program (AMST), which Farmer and Farrell designed and have continued to co-direct since its implementation in the spring of 1973.



Boxes 1, 2, 4 and 5 represent models within the overall systems analysis model. The model for the nature of content (mathematics) was derived from the work of national curriculum groups plus Max Bell's work on the structure and processes of mathematics. The research of Piaget forms the basis for the box dealing with intellectual development. Gagne's hierarchies of types of human learning and the conditions which bring each about are coupled with Ausubel's work on advance organizers and meaningful verbal learning as the basis for box #4. These in turn find application, as does Piaget's work, in the teaching strategies designed to promote the acquisition of specific categories of learning tasks (i.e., concept vs. rule learning, etc.). The taxonomies of Bloom, Krathwohl and Harlow are included in the specification of objectives in all three domains. Finally, feedback giving and getting among components plays a central role in the model.

From the model are inferred most of the seventy-four competencies and the approach to assessment and criterion described in this paper. (A small number of competencies especially those in the mechanics of instruction category were added on the advice of future employers of teachers.) There are also logical interconnections among the seventy-four competencies and overlapping lines of correspondence from the model to the competencies.

Data Collection:

Data were gathered over a period of five semesters from spring 1973 through spring 1975 on the classroom performance of 122 enrollees, of which 100 successfully completed the program. Each student teacher was observed by either Farrell or Farmer a minimum of eight-45 minute teaching periods during the ten weeks of student teaching. A similar number and kind of written observation were also compiled by the public school cooperating teacher to whom each student was assigned. Summative evaluation based on the data resulted in an assessment of one of three kinds: below criterion, meets criterion, or exceeds criterion. (Exceeds criterion was achieved by a very small sample of students.) "Criterion" was defined as the performance of the competency effectively and over at least the final two-three weeks of student teaching. In order to maximize inter-observor reliability in data-gathering, the above researchers frequently observed the same class session, privately recorded relevant data, and then cross-checked the written record. Likewise, these observors regularly read data collected by each other and discussed the kind of inferences to be drawn as related to the AMST instrument.

After an *n* of 100 had successfully completed the program, tabulations of the students' performance on each item were compiled. No data were compiled for the 22 unsuccessful students since they withdrew prior to the final weeks of student teaching.

Data Analysis:

To ascertain the easiest and the most difficult competencies for students to attain, the list of 74 behaviors was examined for extreme scores. Lists were made of the nine behaviors attained by 98% or more math-science student teachers (easiest) and the nine behaviors attained by 50% or less student teachers (hardest). These lists are reported in Tables 1 and 2. In general, the easiest behaviors to attain do not involve

---

Tables 1 and 2 about here

---

direct pupil-teacher interaction, although some of the easy behaviors are related to lesson planning (i.e., using more than one mode during each instructional period; providing a model for correct performance of skills to be learned). The hardest behaviors to attain in almost every case relate to the interactions of teacher and pupils. For example, more than half of the student teachers in this study did not demonstrate criterion-level performance on competencies related to initiating and sustaining class discussions, making productive use of students' questions and answers, or relating present instruction to future lessons.

In order to see the degree to which success or failure with one difficult item was related to performance on other difficult items, correlations were examined for the nine items reported in Table 2. The correlations coefficients for items listed in Table 2 are reported in Table 3. As can be seen, a relatively small but significant relationship exists among most of the

---

Table 3 about here

---

ratings of the nine most difficult behaviors. As might be expected, a tendency exists for the students who attain one of these nine behaviors to attain others of the other eight most difficult behaviors. However, the inter-relationships of these behaviors, although above chance, are not extremely great. Apparently attainment of one behavior is relatively independent of attainment of other behaviors in this cluster.

Some of the seventy four behaviors studied were not exactly the same for math and science student teachers. For example, one set of behaviors concerned clarification of the processes and ideas of mathematics while a similar set of behaviors dealt with the processes and ideas of science. Most of the math and science behaviors were parallel but not identical. In correlational analysis these parallel items were combined. However, a principle components factor analysis was performed only on the 59 teaching behaviors which were listed as exactly the same for math and science teachers. Considered in this paper are the first seven factors which emerged from the analysis. These factors all have eigen values of more than 2 and together they account for 46% of the total variance.

Seven teaching behaviors emerged in Factor 1. These behaviors, along with their factor loadings, are reported in Table 4. In general, these behaviors all seem to reflect

Table 4 about here

classroom alertness. All of the behaviors in Factor 1 involve direct pupil-teacher inter-action through such behaviors as maintaining eye contact, demonstrating enthusiasm, and generating enthusiasm. It is interesting to note that these behaviors are also clustered with the ability to control disruptive student behavior.

Four of the five behaviors in Factor 2, reported in Table 5

Table 5 about here

---

concern the preparation or use of materials by students or by the teacher. The fifth item in the cluster concerns provisions for the "here and now" interests of individual students. Student teachers who provide materials are generally seen as also providing for individual interests.

Only three behaviors emerged in Factor 3. They are reported in Table 6. On the surface, these three behaviors do not seem closely related. One behavior concerns use of item analysis

---

Table 6 about here

---

techniques in testing; the second, a knowledge of contemporary curriculum approaches and the third, the design of individualized instructional materials. However, none of these involve a direct pupil-teacher inter-action.

The six behaviors in Factor 4 seem clearly related. They are reported in Table 7. These behaviors generally relate to

---

Table 7 about here

---

what the student teacher does in the processes of verbal give-and-take with students. Student teachers who involve many students are aware of individual differences. Those who collect feedback are also ones who sequence meaningfully and alter their planned sequence when necessary. Student teachers who fail to display one of these behaviors are likely to have difficulty with others in the set.

In general, the behaviors which are included in Factor 5, (see Table 8) seem to involve careful planning. Included in

---

Table 8 about here

---

the five behaviors in this factor are the development of differentiated assignments, the design of assignments which lead to discovery of concepts, rules, or skills, presentations which capture student attention, and lessons that have the objective of positive attitudinal change. The one behavior that does not seem to directly relate to planning concerns the use of positive techniques to control student behavior.

Behaviors in Factor 6, reported in Table 9, seem to

Table 9 about here

---

reflect a certain intellectual quality on the part of the student teacher coupled with an ability to pace instruction. The five behaviors in this factor include asking thought-provoking questions, including objectives to get higher level intellectual skills and making immediate use of feedback.

Also in the factor are items related to student attention and classroom atmosphere.

Behaviors that had positive loadings in Factor 7, reported in Table 10, usually had a theme of variety and of a concern

---

Table 10 about here

---

for individual differences. Such behaviors as using variety in grouping, in remedial procedures, and in materials were in this cluster. Also in Factor 7 was one behavior with a negative factor loading. Apparently, student teachers who were successful in attaining behaviors related to variety tended to be unsuccessful in relating present instruction to previous learning.

The factor analysis which has been described provides an empirical look at the relationships of 59 of the teaching behaviors that were assessed. Each of the factors includes items that had factor loadings of .30 or more. The specific behaviors that were assessed for each student teacher were based on the conceptual model earlier described. This conceptual model includes six inter-related cells which were labelled (1) Nature of Content to be Learned; (2) Intellectual Development of Students; (3) Objectives Specified; (4) How Humans Learn Various Categories of Content; (5) Instructional Strategy Design; and (6) Feedback Resulting from Implementation of Plans. One of the objectives of this study was the examination of the relationship of the factor analytic structure to the conceptual model.

A number of the specific behaviors to be assessed were classified by Farrell and Farmer into one or another of the components of the model. As previously mentioned, behaviors related to the nature of the content to be learned were not the same for math and science teachers, so these behaviors were eliminated from the factor analysis.

Some behaviors were placed in more than one of the compartments of the model. In Table 11 should be presented the inter-

---

Table 11 about here

---

relationships of behaviors classified logically with the placement of behaviors in the factor structure. As can be seen, 25 behaviors were defined as logically part of the category of feedback resulting from implementation of plans, 19 to instructional strategy design, and 11, 5, and 4 behaviors to the other categories of the logical model. (Recall that a behavior may be placed in more than one category.) Reading down the table, Factor 1 behaviors appeared nine times in one or another of the logical categories. Six of the seven behaviors in Factor 1 were placed logically in the feedback category. This category as logically considered had twenty-five behaviors. Thus Factor 1 behaviors are clearly part of feedback, but not all of feedback as logically defined. Factor 2 behaviors seem to split between the intellectual development and instructional strategy categories. Behaviors in Factors 3 through 7 seem to be widely spread over the logical categories. Also 1/8 of the behaviors assigned to logical categories do not appear in any of the first seven factors.

These results are to be expected for a number of reasons. For example, as can be seen in Table 1, some behaviors were attained by all or nearly all the student teachers in the study. The behaviors may be logically essential to successful teaching, but they will not predict any of the variance between teachers. Some behaviors were judged important for teaching and included in the assessment but not related to the logical model. These behaviors might emerge in the factor analysis but they could not interface with the model.

Ideally, the logical model and the factor analysis should go together to help us understand teaching behavior more fully. By specifying behaviors and categories of behaviors we can direct the attention of students to just what they are expected to learn. By analyzing these behaviors that differentiate student success we should be able to devise means to help more students to be able to attain criterion behavior.

Conclusions:

Results such as those presented in this paper must always be assessed from the vantage point of related, but not measured, elements. In particular, the definition of "criterion" employed by the researchers necessitates that data which could be described by a continuous scale is described by a two point, apparently discrete, scale. In other words, a student teacher who has not met criterion on a competency may have (1) never tried to demonstrate the behavior, (2) tried, but at inappropriate times or in ineffective ways, (3) tried and been effective sometimes and ineffective other times, or many other combinations of behavior. For this reason, the results of the data analysis must be interpreted with some caution. It is reasonable to conjecture that a study in which data was collected over a twenty week or forty week period might have resulted in as yet unidentified factors. However, the heavy factor loadings that exist in this study suggest that the seven factors identified here would not likely be discarded in a longer term study.

A second related element pertains to the dual use of the instrument as both an instructional and an evaluative tool and the use of the model as the central focus of instruction. Thus, some input-output disparity is represented by the instrument and the model. The data analysed in this study is output data which resulted from the ultimate use of the instrument in summative evaluation. The logical connections between the model and the competencies can be described as input relationships--inputs which are heavily related to the cognitive domain of instruction. Yet all factors other than Factor 3 appear to also lean heavily on the affective domain.

One of the tantalizing, but by no means, unexpected questions to arise from this inference is that of the effect of personality of the student teacher on the ability to meet criterion and the related question of the nature of instructional techniques likely to make a positive impact in the affective area. Some of these questions will be the subject of the next phase of data analysis as will be analysis of the data on competencies peculiar to mathematics teaching versus those peculiar to science teaching.

TABLE 1

Competencies Which Ninety Eight Per Cent or More of Students Attained

Competencies measured	Below Criterion	Met Criterion	Exceeded Criterion
1. Matched test items to instruction objectives	0	98	2
2. Constructed tests to be consistent with emphasis of instruction	0	98	2
3. Maintained a physical environment conducive to learning (e.g., lights, heat, ventilation)	0	99	1
4. Included those objectives designed to effect the attainment of intellectual skills beyond the levels of recall and type problems	0	100	0
5. Practiced safety precautions during laboratory and demonstration work (science only)	0	100	0
6. Used more than one mode during each instructional period	1	97	2
7. Used out-of-class time to help individual students	2	93	5
8. Demonstrated clerical efficiency with respect to the paperwork of the teacher	2	96	2
9. Provided a model for correct performance of skills to be learned (to enable students to get feedback on their efforts)	2	97	1

TABLE 2

Competencies Which Half or More of Students Did Not Attain

Competencies measured	Below Criterion	Met Criterion	Exceeded Criterion
1. Initiated and sustained discussions among students	65	35	0
2. Designed assignments to lead to discovery of concepts, rules, or skills to be taught in subsequent class sessions	62	36	2
3. Provided students with experiences in using problem-solving strategies (math)	60	40	0
4. Designed <u>differentiated</u> assignments based on student interests and levels of previous learning	59	41	0
5. Developed productive ways of making use of students' questions and answers	58	42	0
6. Distinguished between generalizations obtained from data and those obtained by deductions from assumptions (math) Identified anthropomorphic and teleological explanations as being the antithesis of science (science)	53	47	0
7. Developed presentations which captured student attention at the start of lessons	53	45	2
8. Related present instruction to future lessons.	51	49	0
9. Asked thought-provoking and/or open-ended questions	50	48	2

TABLE 3

Correlations Among the Most Difficult Criteria

	23	27	47	42	22	48	29	33	21
23	1.00	.24**	.30**	.16	.10	.19*	.19*	.20*	.03
27		1.00	.35**	.45**	.24**	.16	.30**	.05	.22*
47			1.00	.40**	.34**	.25**	.36**	.26**	.24**
42				1.00	.07	.11	.37**	.16	.33**
22					1.00	.34**	.17*	.12	.19*
48						1.00	.30**	.20*	.36**
29							1.00	.22*	.36**
33								1.00	.24**
21									1.00

*significant at .05
**significant at .01

TABLE 4

Items in Factor 1 15.6
(Variance explained equals ~~9.35~~ percent)

Competencies Measured	Factor Loading
Maintained eye contact with a wide sampling of students	.963
Conveyed to students the teacher's awareness of their interests and points of view	.945
Demonstrated ability to work with single students or small groups while exhibiting awareness of the general activities in the room	.942
Generated enthusiasm for the subject among students	.933
Demonstrated enthusiasm for the subject via verbal and/or non-verbal behavior	.924
Utilized sequences of developmental questions	.901
Demonstrated the ability to control disruptive student behavior	.670

TABLE 5

Items in Factor 2 8.9
(Variance explained equals ~~5.35~~ percent)

Competencies Measured	Factor Loading
Utilized laboratory activities (student manipulation of materials)	.762
Demonstrated initiative in locating and preparing laboratory activities	.669
Used real objects and/or physical models in demonstrations	.608
Made use of a variety of available materials and media	.594
Provided for applications of subject matter based on the "here and now" interests of individual students	.412

TABLE 6

Items in Factor 3 5.6
(Variance explained equals ~~3.37~~ percent)

Competencies Measured	Factor Loading
Used item analysis technique to analyze the test's validity, potential weakness of instruction, and learning problems of individual students	.731
Evidenced a knowledge of contemporary curriculum approaches and programs	.648
Designed individualized instructional materials based on varying objectives and learning styles	.575

TABLE 7

Items in Factor 4 4.5
(Variance explained equals ~~2.69~~ percent)

Competencies Measured	Factor Loading
Developed productive ways of making use of student questions and answers	.676
Used teaching strategies consistent with the intellectual maturity of the students	.603
Involved nearly all students, verbally or non-verbally, in the ongoing activities	.573
Made immediate use of feedback to alter the planned sequence of activities	.570
Collected feedback frequently from a broad sampling of students	.491
Sequenced in ways meaningful to students	.424

TABLE 8

Items in Factor 5 3.9
(Variance explained equals ~~2.36~~ percent)

Competencies Measured	Factor Loading
Designed differentiated assignments based on student interests and levels of previous learning	.681
Used positive techniques to prevent and/or control student behavior	.586
Included those objectives designed to effect positive attitudinal changes toward the subject	.525
Designed assignments which led to the discovery of concepts, rules or skills to be taught in class	.475
Developed presentations which captured student attention at the start of lessons	.308

TABLE 9

Items in Factor ~~6~~ 3.6
(Variance explained equals ~~2.16~~ percent)

Competencies Measured	Factor Loading
Arranged activities so that student attention was maintained throughout the lessons	.681
Provided a classroom atmosphere which encouraged students to demonstrate regard for the rights and property of others	.609
Made immediate use of feedback to pace instruction	.502
Asked thought-provoking and/or open-ended questions	.471
Included those objectives designed to effect the attainment of intellectual skills beyond the levels of recall and stereotype problems	.455

TABLE 10

Item in Factor 7 3.5
(Variance explained equals ~~2.09~~ percent)

Competencies Measured	Factor Loading
Initiated and sustained discussions among students	.708
Used a variety of procedures such as grouping within a class and assignment of individual or small group projects	.640
Used a variety of remedial procedures based on student feedback	.553
Related present instruction to previous learning	-.334
Modified materials to meet the special needs of the student and the limitations of the classroom	.389

TABLE 11

Inter-relationships of Behaviors Classed Logically and by Factor Analysis

Logical Categories	Number of Behaviors by Factor 1	2	3	4	5	6	7	*	TOTAL
Intellectual Development of Students	1	3	1	2	1	0	3	0	11
Objectives Specified	1	0	0	0	1	1	0	2	5
How Humans Learn Various Categories of Content	0	0	1	1	0	0	1	1	4
Instructional Strategy Design	1	4	0	2	2	2	2	6	19
Feedback Resulting from Implementation	6	0	2	3	2	2	1	9	25
TOTAL	9	7	4	8	6	5	7	18	64

*Not in first seven factors